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Incorporating respondent uncertainty when estimating willingness to pay for protecting critical habitat for threatened and endangered fish

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Abstract. A comparison of the standard dichotomous choice contingent valuation model to alternative modifications that explicitly incorporate respondent uncertainty is performed to estimate economic benefits of protecting critical habitat for nine threatened and endangered fish species living in the Colorado, Green, and Rio Grande River basins. The standard dichotomous choice contingent valuation model estimated a value of $268 per household, which was compared to values ranging from $50 to $330, depending on how respondent uncertainty was explicitly incorporated into the dichotomous choice model. For this data set, incorporating respondent uncertainty had the effect of increasing the goodness of fit and decreasing the standard error of estimated willingness to pay in only one of five models tested.

1. Introduction

The Endangered Species Act (ESA) requires federal agencies, including the Bureau of Reclamation (BOR), to avoid jeopardizing the continued existence of threatened and endangered (T&E) species, including fish species in the four corners region. Recovery measures comprise reoperation of dams, installation of fisheries protection measures, and in-stream flow releases. These actions result in direct costs and opportunity costs of reduced irrigation and hydropower benefits. These economic losses are easy to see and quantify, and they tend to be concentrated among a small number of water users who publicize their losses.

Economic benefits, however, are more difficult to measure, but people have shown that they value the preservation of a wide variety of threatened and endangered species, from the obscure striped shiner (a fish in the Milwaukee River) to the bald eagle and whooping crane, as summarized by *Loomis and White* [1996]. While values per household may be quite low for some species, the public good nature of preserving endangered species results in large aggregate values, as millions of households throughout the United States can simultaneously enjoy the benefits of knowing these species still exist. However, the dispersed nature of the public good benefits provide much less of an incentive for beneficiaries of preservation of endangered species to become actively engaged in the policy process.

Society often realizes real opportunity costs from protecting T&E species and their habitats in the form of higher costs of production or valuable uses foregone. As such, economic benefits must be defined and measured in a commensurate fashion by managing agencies. Measuring benefits using willingness to pay (WTP) is the currently accepted norm among Federal agencies for benefit-cost analysis [*U.S. Water Resources Council*, 1983] and natural resource damage assessment [*Department of Interior*, 1986].

Since the public owns T&E species, willingness to accept for avoiding losses would often be the more appropriate measure for estimating benefits. However, the public's unfamiliarity with being offered compensation as compared to being asked to pay for programs, coupled with difficulties in empirical measurement, results in nearly all studies using WTP as the measurement technique. The reliance on a conservative measure such as WTP may help to offset the concern that the survey technique used to elicit WTP (discussed below) may overstate values because of the hypothetical nature of the payment. While the ESA does not allow coordination of economics in the listing decision, it does in the decision over how much critical habitat to designate. Thus benefits and costs both play a role.

1.1. Contingent Valuation Method

Existence of threatened and endangered species is not a product that is sold in markets, but it has value to society. Because of lack of price, economists have developed a hypothetical market method, called the Contingent Valuation Method (CVM), that uses a survey to measure household WTP to protect a species in a particular location. A CVM survey is a standardized and widely used method for obtaining WTP and involves developing a hypothetical market or referendum as a vehicle by which an individual reveals his or her WTP. CVM is recommended for use by Federal agencies for performing benefit-cost analysis [*U.S. Water Resources Council*, 1983] and for valuing natural resource damages [*U.S. Department of Interior*, 1986], and it was upheld by the Federal courts [*State of Ohio versus U.S. Department of Interior*, 1989]. Recently, a panel including two Nobel laureate economists, an environmental economist, and a survey research specialist reviewed the CV process, and while they felt that this method had limitations, they concluded that CVM can produce esti-

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mates reliable enough to be the starting point for administrative and judicial determinations [*Arrow et al.*, 1993].

1.2. Previous Research on the Economic Value of T&E Species

Loomis and White [1996] provide a review of estimates of economic benefits for about 20 T&E species, about half of those estimates unpublished. Their meta-analysis of the values suggests that most of the variability in values of species can be explained by a few specific variables. In particular, the value per household is largely determined by the size of the change in species population being offered in the survey, whether visitors or households are being surveyed, whether the species is a bird, and whether annual or a one-time willingness to pay amount was being asked. Using both a linear and a double log functional form, the regressions explained between 58% and 68% of the variation in per household WTP. This high explanatory power for a cross-sectional study is encouraging, regarding the internal consistency of CVM-derived WTP values. One important problem, though, ignored in valuation of T&E species to date, is omission of the issue of respondent uncertainty. We now turn to that issue.

1.3. Past Research on Respondent Uncertainty

Most individuals are not familiar with many T&E species and have no prior experience paying for species protection. Many individuals realize personal satisfaction from knowing these species exist but have not devoted much time contemplating how much they would pay. If they spent the time to reflect on the tradeoffs between household costs and preservation of species, they could refine their preferences. However, the one-shot nature of CVM survey responses may not provide sufficient repetition for generating stable preferences. Of course, this uncertainty has been one of *Diamond and Hausman*'s [1993] criticisms of measuring nonuse values by CVM.

While CVM may not provide the opportunity to stabilize preferences through repeat purchasing behavior, respondents may be able to express the level of confidence in their dollar bids and this information can be incorporated into the statistical analysis. Those individuals who have extensive prior knowledge of the environment or species in question may have well-defined preferences and great certainty in their responses, while those with little or no knowledge may have less-defined preferences and therefore more uncertainty about their answers. Incorporating the stated uncertainty of respondents into the statistical model could improve the estimation and accuracy of the analysis [*Manski*, 1995].

Several approaches have been recently developed to incorporate respondent uncertainty into CVM. *Ready et al.* [1995] used a polychotomous choice question format where the respondent had a choice of six responses to a single bid amount: "definitely yes," "probably yes," "maybe yes," "maybe no," "probably no," and "definitely no." They found that allowing for uncertainty increased WTP. *Welsh and Bishop*'s [1993] multiple bounded approach provided a similar range of responses for the full range of bid amounts. They found little change in the level of WTP, but the estimates had reduced variability.

A different approach was employed by *Li and Mattsson* [1996], who used a two-step approach. They first used a conventional dichotomous choice WTP question followed by having the respondent perform a "postdecisional" rating of the certainty of the response to the WTP question. This certainty rating is incorporated into the likelihood function directly. The net result reduced both the mean WTP and the variance of the estimated WTP.

Champ et al. [1997], *Johannesson et al.* [1996], and *Polasky et al.* [1996] show the importance of addressing respondent uncertainty on WTP estimates. Champ et al. compared actual contributions of a sample of Wisconsin residents to remove roads on the north rim of the Grand Canyon with stated WTP from a separate sample of Wisconsin residents. The stated WTP of $79 was several times the actual payment of $9. Respondents to the stated WTP questionnaire were also asked how certain they were of their response using a 10-point scale where "10" was "very certain" and "1" was "very uncertain." Champ et al. recoded all "yes" responses with certainty response of less than a 10 to a "no." This recoding technique led to reduction in the estimated WTP to about $12, which is very similar to the actual mean payment amount of $9. This provides strong evidence in favor of incorporating uncertainty into the analysis.

Johannesson et al. [1996] estimated WTP for a box of chocolates using a similar technique and found that recoding resulted in statistical underestimation of the cash WTP. If only completely certain "yes" responses were retained as "yes" answers, the authors concluded that too many responses were recoded "no." The difference between the conclusions of *Champ et al.* [1997] and Johannesson et al. may be due to the potential for free riding in the public good in contrast to the private good study.

Polasky et al. [1996] performed a different type of validity study, comparing intended voting behavior in an actual referendum for open space. While there was not a perfect match of characteristics between voters and survey respondents, the results shed light on the issue of dealing with uncertain voters. The actual referendum had about 44.8% voting "yes." Excluding those individuals who were uncertain and those who refused to answer, the various sample frames answering the CVM question all yielded 53–54% "yes" responses, significantly different from the actual vote. When the uncertain respondents and those refusing were coded "no," the percentage of "yes" votes dropped to about 40–43%, slightly understating the actual vote pattern. Polling literature support this result, suggesting that most undecided voters choose "no" in the actual vote [*Magelby*, 1989].

The purpose of our paper is to develop new methods that utilize information on response uncertainty and to compare these to recently proposed approaches for incorporating uncertainty into statistical models for estimating WTP. We compare the existing and new methods in terms of variance of mean WTP and goodness of fit of the logit model.

1.4. Measuring and Incorporating Respondent Uncertainty

For comparison, we estimated the standard dichotomous choice (STD) WTP using the logit model:

$$\text{Prob (yes)} = 1 - \{1 + \exp[B_0 - B_1 (\$X)]\}^{-1} \quad (1)$$

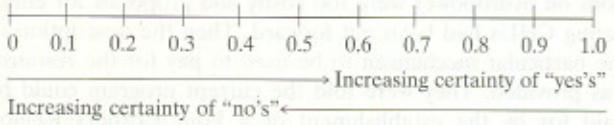
where $\$X$ is the dollar amount the individual is asked to pay, and B_0 and B_1 are the intercept and slope coefficients, respectively. This model was estimated twice, once using the same variables as in the other models and a second time including the uncertainty value as one of the independent variables.

The following models more fully utilize the information contained in the 1–10 postdecisional rating that respondents provide regarding the certainty of the willingness-to-pay response.

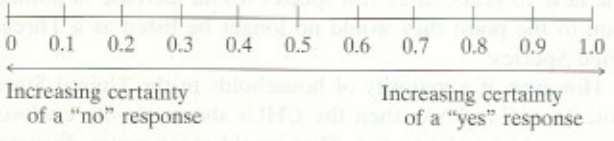
The first model extends the *Champ et al.* [1997] and *Polasky et al.* [1996] approach of recoding uncertain "yes" responses as "no's" by evaluating a cutoff point for a "yes" response to count as a "yes" and created a model called YES10. Based on our scale of 1 being "very uncertain" and 10 being "very certain," YES10 recoded all "yes" responses to "no's" if the respondent did not have a certainty response of 10, following the suggestion of Champ et al.

Two models were then designed to explicitly incorporate more of the uncertainty information into the logistic regression model. These two models assume that the "yes" and "no" responses are equally uncertain and therefore rescale both the "yes" and the "no" answers but retain the individual level data using the recoded probabilities directly. We used two approaches for rescaling.

The first approach for recoding both "yes" and "no" WTP responses is similar to the approach by *Li and Mattsson* [1995]: overlaying the "yes" and "no" certainty levels on the same scale. This requires rescaling both the "yes" and "no" responses between 0 and 1.0, which we refer to as the LIMATT model. Their approach assumes that "a yes response with 40% confidence, for example, is equivalent to a no answer with 60% confidence" [*Li and Mattsson*, 1995, p. 264]. This is shown as follows:



Our next approach gives greater weight to the actual response to the WTP question. That is, the "yes" answers are rescaled only between 0.5 and 1.0, depending on certainty level, while the "no" respondents are rescaled only between 0 and 0.5 and referred to as the Symmetric Uncertainty Model (SUM). The probabilities then are arrayed along a continuum as follows:



The SUM suggests a structure which uses the uncertainty to modify the strength of the "yes" or "no" response but retains the respondent's "yes" or "no" answer. We believe this is more consistent with literal interpretation of the survey answers than *Li and Mattsson*'s [1995] approach. SUM can also be estimated with Limdep [*Greene*, 1992], using logistic regression.

As suggested by reviewers, two additional models were estimated. The first is a model called the Standard Dichotomous Choice Certainty model (STDC) because it is identical to the standard dichotomous choice model except that it includes the uncertainty scale as an independent variable in the logit model. The second model, called the Standard Dichotomous Choice Weighted model (STDW), also used the uncertainty variable as part of the estimation, but instead of using it as an independent variable, it creates a weight to affect the likelihood function of the individual response.

1.5. Comparisons of Approaches

Li and Mattsson [1995] as well as *Manski* [1995] suggest that with more information incorporated into the statistical model, goodness of fit will increase and the WTP estimates will be more precise. We measured goodness of fit on the basis of the models' abilities to predict the actual responses (referred to as PR). This is the percentage of correct predictions, a commonly used gauge of binary model performance. For all models except LIMATT and SUM, the Limdep results provided this information. However, for LIMATT and SUM, the parameters of the logit equations were used with the individual data to predict the response. This predicted response was compared to the actual response to determine the level of correct predictions. Precision or efficiency of the WTP estimate will be measured by estimating a standard error (SE) for the mean WTP estimate at a 90% confidence level.

Our specific hypotheses for goodness of fit and for precision are the following:

$$H_1^O: \quad PR_{LIMATT} = PR_{SUM} = PR_{STDW} = PR_{STDC} = PR_{STD} = PR_{YES10} \tag{2}$$

$$H_1^A: \quad PR_{LIMATT} > PR_{SUM} > PR_{STDW} > PR_{STDC} > PR_{STD} > PR_{YES10} \tag{3}$$

$$H_2^O: \quad SE_{LIMATT} = SE_{SUM} = SE_{STDW} = SE_{STDC} = SE_{STD} = SE_{YES10} \tag{4}$$

$$H_2^A: \quad SE_{LIMATT} < SE_{SUM} < SE_{STDW} < SE_{STDC} < SE_{STD} < SE_{YES10} \tag{5}$$

In addition to the STDC model, we use a t test to determine if the uncertainty variable is statistically significant.

1.6. Statistical Estimation of the Logit Model

Since the printed dollar amount varies across the sample of respondents, the voter referendum format requires the analyst to statistically trace out a demand-like relationship between probability of a "yes" response and the dollar amount using a qualitative response model such as logit or probit [*Hanemann*, 1984]. The basic logistic regression model was given in (1). From (1), *Hanemann* [1989] provides a formula to calculate the mean or expected value of WTP assuming WTP is greater than or equal to zero. The formula is

$$\text{Mean WTP} = (1/B_1) \ln (1 + e^{B_0}) \qquad \text{WTP} \geq 0 \tag{6}$$

For this analysis, B_1 is the coefficient estimate on the bid amount and B_0 is the sum of the estimated constant plus the product of the other independent variables times their respective means for each respondent. The individual means are then averaged to determine a average mean of WTP for the sample.

Hanemann [1989] also provides a formula to calculate the median of WTP allowing for WTP to be less than zero. The formula is

$$\text{Median WTP} = (B_0/B_1) \tag{7}$$

with B_1 and B_0 representing the same terms as before. Because the median allows for negative values, it allows for the possibility that some people would have to be compensated for protection of critical habitat for these species.

2. Case Study Protecting Critical Habitat for Nine T&E Fish Species in Rivers of the Four Corner States

This case study uses the CVM to quantify public economic value for preserving critical habitat units (CHUs) that are

Table 1. Nine Species of Threatened or Endangered Fish in the Four Corners Area, by River

River	Fish
Colorado	bonytail chub Colorado squawfish humpback chub razorback sucker
San Juan and Green	Colorado squawfish razorback sucker
Virgin, Utah	Virgin River chub woundfin
Gila	loach minnow spikedace
Rio Grande, New Mexico	silvery minnow

habitat to nine T&E fish species in the four corners region of the United States. Nine species of fish are listed as threatened or endangered and have critical habitat designated in six rivers of the four corners states, as shown in Table 1. The impact of having critical habitat designated is that river flows are affected through instream flow requirements and altered management of hydropower facilities.

CHUs are designated as necessary for survival and recovery of a designated species under section 7 of the ESA. These areas allow for recovery of these fish species with the goal that they will be removed from listing. The primary habitat components for these fish species are rivers that provide or have the potential to provide life requisites. Criteria for delisting requires a stable or increasing population after 10 years, and habitat trends must be stable or increasing over the long-term [*U.S. Department of the Interior*, 1995].

The U.S. Fish and Wildlife Service designated CHUs on 2456 river miles including segments in major cities such as Grand Junction, Colorado, and Albuquerque, New Mexico, plus the Colorado River downstream of Glen Canyon Dam. These include the Colorado River through Glen Canyon National Recreation Area and Grand Canyon National Park. Portions of the Gila River, including stretches through Phoenix, Arizona are also designated.

2.1. Survey Design

Prior to designing the actual survey three focus groups were held, one each in Fort Collins, Colorado; Albuquerque, New Mexico; and Phoenix, Arizona, leading to revisions based on the suggestions and comments of the participants in these groups. Following the focus groups the research team developed a complete mail booklet and survey script, used to pretest a small sample of households throughout the United States.

Feedback suggested further refinements, a more explicit voting emphasis, ways to reduce repetition, and improvement in survey instructions. Responses to the pretest bid amounts (along with ongoing research on the economic value of the silvery minnow by Robert Barrens at University of New Mexico) formed the basis for establishing the bid amounts in the final survey. The final questionnaire was typeset into a 12-page booklet.

2.2. Survey Structure

The first section of the survey allowed the respondents an opportunity to reflect on why they might care about the endangered species and was used for collecting their thoughts on the topic [*Cummings et al.*, 1986]. The first set of questions asked about the relative importance of federal lands for providing habitat for endangered species versus using resources for extraction and jobs.

A five-point Likert scale allowed individuals to agree or disagree with a set of attitude questions to measure how utilitarian they were versus how preservation-oriented they were. These responses also provided insight into the responses to the WTP question and have been used in other research [*Barrens et al.*, 1996].

Our CVM survey followed the standard three-element design: (1) portrayal of the resource to be valued, (2) description of the particular mechanism to be used to pay for the resource, and (3) the question format used to elicit the respondent's dollar amount of WTP. The resource being valued was the 2456 miles of CHUs described earlier. Survey respondents were provided detailed maps with the CHUs highlighted. Protection involved habitat improvements such as fish passageways as well as bypass releases of water from dams to imitate natural water flows needed by fish. Table 1 shows the listing of fish species by river that was printed in the survey.

Households were told that some State and Federal officials thought the costs of the habitat improvements and the restrictions on hydropower were too costly and proposals for eliminating CHUs had been put forward. Then the description of the particular mechanism to be used to pay for the resource was provided. They were told the current program could be paid for by the establishment of a Four Corners Region Threatened and Endangered Fish Trust Fund. Efforts to raise funds would involve all U.S. taxpayers contributing to this fund. If a majority of households vote in favor, the fund would maintain CHUs for the nine T&E fish species to avoid extinction. This would be accomplished through water releases from Federal dams timed to benefit fish and the purchase of water rights to maintain instream flows. The survey stated that within the next 15 years, three fish species would increase in population to the point they would no longer be listed as a Threatened Species.

However, if a majority of households in the United States vote to not approve, then the CHUs shown on the enclosed map would be eliminated. That would mean water diversion activities and maximum power production would occur, reducing the amount of habitat for these nine fish species, and that as a result, biologists estimate that it is very likely that four of the nine fish species will be come extinct in 15 years.

This information was followed by the question format used to elicit the respondent's dollar amount of WTP which asked each household how they would vote, considering the price indicated. This referendum format is recommended by the panel on CVM [*Arrow et al.*, 1993]. The exact wording of the questionnaire was as follows:

> Suppose a proposal to establish a Four Corners Region Threatened and Endangered Fish Trust Fund was on the ballot in the next nationwide election. How would you vote on this proposal?
>
> Remember, by law, the funds could only be used to improve habitat for fish.
>
> 1. If the Four Corners Region Threatened and Endangered Fish Trust Fund was the only issue on the next ballot and it would cost your household $_____ every year, would you vote in favor of it? (Please circle one.)
>
> YES NO

The dollar amount, which is blank in this example, was filled

Table 2. Coefficients From the Logit Estimates for Alternative Models, Combined Sample

Variable	Mean	STD[a]	STDC[b]	STDW[c]	YES10	SUM	LIMATT
Constant	1	1.12 (1.93)	0.49 (0.77)	1.55[d] (2.29)	−2.47[e] (−2.77)	0.98[d] (2.23)	0.88[e] (2.20)
FISHBID	66	−0.0045[e] (−4.42)	−0.0045[e] (−4.33)	−.0049[e] (−4.67)	−0.0070[e] (−3.15)	−0.0039[e] (−4.98)	−0.0033[e] (−4.90)
Income[f]	55	0.011[e] (4.04)	0.0091[e] (3.34)	0.0087[e] (3.19)	0.0068[d] (2.34)	0.0065[e] (3.22)	0.0031 (1.70)
PROTECT	−4.6	0.50[e] (7.58)	0.48[e] (7.59)	0.54[e] (7.24)	0.32[e] (3.37)	0.40[e] (8.29)	0.33[e] (7.87)
PROTJOB	−6.9	−0.19[e] (−3.35)	−0.18[e] (−3.29)	−0.19[e] (−3.05)	−0.35[e] (−4.27)	−0.17[e] (−3.93)	−0.16[e] (−4.00)
FSHCERT	7.9	...	0.098[d] (2.26)	...	...	...	...

	STD[a]	STDC[b]	STDW[c]	YES10	SUM	LIMATT
Mean WTP, $	268	276	265	50[e]	301[d]	330[d]
Median WTP, $	132	169	144	−184	159	163
CI 95%, $	255–281	262–280	252–278	48–52	288–314	317–343
Predictability (PR)	75.2	73.4	74.7	81.1	73.6	74.0
Standard Error (SE), $	6.80	6.90	6.70	1.80	6.60	6.40

Here t statistics are given in parentheses.
[a]Standard DC model that does not include the uncertainty variable.
[b]Standard DC model that does include the uncertainty variable.
[c]Standard model without the uncertainty variable but weighted by the uncertainty variable in addition to adjustments for sampling weights.
[d]Significant at the 95th level.
[e]Significant at the 99th level.
[f]Income measured in thousands.

in with one of 14 amounts ranging from $1 to $350, randomly assigned to survey respondents. The range was picked such that at the low end, anyone that valued preserving the fisheries protection would very likely indicate they would pay $1–3, while almost no one was expected to pay $350 per year.

On the next page of the survey, respondents was asked to determine how certain they were when answering the WTP question. The wording in the survey was as follows:

> 2. On a scale of 1 to 10, how certain are you of your answer to the previous question? Please circle the number that best represents your answer if 1 = not certain and 10 = very certain.
>
> 0 1 2 3 4 5 6 7 8 9 10
>
> not certain ⟵ ⟶ very certain

This linear certainty scale is patterned after that of *Champ et al.* [1997]. Collaboration with psychologists may be able to improve upon this scale in the future (including appropriate nonlinearity).

2.3. Sample Frame and Survey Mailing

The questionnaire was sent to a random sample of 800 households in the four corner states of Arizona, Colorado, New Mexico, and Utah (with the proportions based on the states' relative populations) and an additional 800 households in the rest of the United States. The sample was provided by Survey Sampling, Inc., a company that specializes in providing representative samples and one that has been frequently used by researchers in the past. The overall survey design and mailing procedure follows *Dillman*'s [1978] Total Design Method (first mailing, postcard, second mailing). Each individual was sent a personalized cover letter on university letter head with an original signature. A dollar bill was included with the first mailing as a token of appreciation and to increase the response rate. Both the outgoing and return envelopes had a first class postage stamp affixed to further distinguish the mailing from bulk mail. A second mailing was performed (without the $1 bill) to nonrespondents.

2.4. Survey Results

We received 718 responses, which after deleting undeliverable surveys and deceased, yielded a response rate of 53.9%. Of these, 362 were returned from residents of the four corners region and 356 from the rest of the United States. Very few respondents indicated membership in environmental organizations: only 12% of the four corners residents and 14% of the rest of the United States sample stated they belong to at least one of these organizations. This is an encouraging sign regarding the representativeness of the sample. That is, we did not receive surveys just from those strongly interested in the environment.

Since we had oversampled the residents of the four corners region relative to their representation in the U.S. population, we adjust for this when pooling the data from the two subsamples. In particular, the U.S. respondents are weighted more heavily in the likelihood functions that follow.

Besides the bid amount, independent variables include income and proxies for tastes and preferences, called PROTECT and PROTJOB. PROTECT was the sum of the answers on the Likert scale from the questions asking about the desirability of protecting plants and animals. PROTJOB was the sum of the responses related to the rights of business to extract resources and be protected from loss of jobs. Because the variable PROTECT was the sum of four questions and the variable PROTJOB was the sum of two questions, PROTECT was divided by 2 so that the coefficient would compare to the PROTJOB coefficient. Also, because the Likert scale asked the respondent to answer "1" for strongly agree and "5" for strongly disagree, the coefficients to these variables would be intuitively reversed. Therefore each was multiplied by −1 to reverse the signs of the coefficients. These variables are relevant as they represent the feelings of the respondents and show how their preferences affect their response to the referendum question. In addition, for the model STDC, the variable for uncertainty (FSHCERT) was included. This is the 1–10 uncertainty value, indicated earlier, as specified by respondents.

Table 3. Percentage of "Yes" Responses for Each Bid Amount

Percent "Yes"	Bid Amount
69	1
80	3
72	5
63	10
57	15
59	20
59	30
60	40
38	50
39	75
40	100
31	150
36	200
38	350

2.5. Statistical Results

Table 2 provides the coefficients, t statistics, and variable means for the logit equations. The coefficients on all variables are statistically significant. The coefficients for the bid amount (FISHBID) are negative, indicating that as bid amount increases, the respondent is less likely to pay this amount. The coefficients for income have positive signs: as incomes increase, willingness to pay increases.

PROTECT generated positive significant signs on these coefficients, showing strong preferences about protecting endangered species and were more willing to bid higher dollar values. Those respondents with high scores on the PROTJOB variable emphasize employment above T&E protection, and this results in significant negative signs on the coefficients, implying less likelihood of paying to protect the nine T&E fish.

In addition to the signs being as anticipated for the independent variables, Table 3 shows that the respondents provided responses as expected. As the bid amounts increased, the percentage of "yes" responses decreased. For example, the percentage of respondents who answered "yes" to $5 was twice (72%) the percentage that answered "yes" at $200 (36%).

Mean and median WTP values were calculated using (6) and (7), respectively, with the resulting values shown in Table 2, along with 95% confidence intervals, the percent correct predictions, and the standard errors. The mean WTP for the standard referendum question was $268 per household. This is the value for protecting all nine fish and 2456 river miles of critical habitat in the seven rivers. In particular, the WTP is to avoid extinction of four fish species and increase the population of three species so they can be delisted. Our confidence interval does not include, and is greater than, the $28.73 value estimated by *Barrens et al.* [1996] for just the silvery minnow in the Rio Grande River in New Mexico (one of the nine fish species in our study). In comparison, the two models that were similar to the standard DC model but included the uncertainty response, STDC and STDW, are also shown on Table 2. While the variable FSHCERT was significant, these models did not have a significant difference in mean values, with values of $276 and $265, respectively, which vary by only a few dollars.

YES10 had the lowest mean, of $50, a value significantly lower than the standard DC estimate and similar to results of *Champ et al.* [1997]. The mean WTP for the SUM model was $301 and for the LIMATT model $330, also significantly different than the standard DC model, as confirmed by the standard errors, shown in Table 2.

2.6. Results of Hypothesis Tests

Hypothesis 1 suggested that the models using uncertainty information should show improvement in goodness of fit using the PR. Generally, we found this to be partially true. The YES10 model, which recoded uncertain "yes" responses to "no" responses, had slightly larger PR estimates. We also hypothesized that the other models that more fully utilize the uncertainty information in the estimation of the logit model should have better goodness of fit, but because the prediction scores were so similar with the PR scores for SUM and LIMATT models slightly lower than the STD model, we concluded there was no difference in goodness of fit.

Table 2 also presents the 95% confidence intervals as well as our measure of the precision of estimated WTP, called SE, the standard error of the mean WTP. The smaller the value, the greater the efficiency in the estimate of the WTP. As in the PR test, only the YES10 model has a value much different form the STD model. The SE for YES10 is 1.8, compared to 6.8 for the STD model. The other models ranged between 6.4 and 6.9, very similar to the STD SE of 6.8. While the SUM and LIMATT models were slightly lower, with values of 6.6 and 6.4, the difference is slight.

2.7. Policy Implications

For the purpose of policy decisions this study showed that there are significant values to protecting these nine T&E fish species. All of the estimates of mean WTP are statistically different from zero, with the lower bound of the most conservative estimate being $50 (YES10 model). Using the range of all the models, the lowest mean WTP per household is $50 and the highest mean WTP, from the LIMATT model, is $330. The standard dichotomous choice CVM recommended by the NOAA panel yields an estimate of $268 per household. While these values represent a broad range, a resource manager can recognize that if there are close to 100 million households in the United States, the economic benefit of protecting these habitats is substantial. As noted in the introduction, the YES10 model has been shown to have some claim to meeting criterion validity, so that the national benefit estimate could be about $4.6 billion, even assuming nonrespondents have zero WTP.

3. Conclusion

This study found WTP for preservation of critical habitat areas for the nine threatened and endangered fish species in the four corners region of the United States to be $268 using the standard dichotomous choice model for estimating nonmarket values. This value is substantially greater than the value found by *Barrens et al.* [1996] for one of these nine species. The confidence intervals around our mean WTP did not include zero, implying that this WTP was statistically positive. Efforts at recoding the "yes" responses, similar to those by *Champ et al.* [1997] and *Johannesson et al.* [1996], also resulted in reduced levels of WTP, with confidence intervals not overlaying those of the standard dichotomous choice model. The results of Champ et al. and Johannesson et al. implied that recoding provided for a more realistic estimate of hypothetical WTP.

Past literature suggested that models incorporating uncertainty would be more efficient at estimating the WTP. However, this expectation did not prove to be true, as the PR and

SE values were not effectively improved by the models, except for the YES10 model, using the uncertainty information. The degree of uncertainty is self-assessed by survey respondents and may contain a level of uncertainty itself. Because of this, the variable may be adding more statistical noise than valuable information to the models, leading to less efficient estimates.

The results of *Champ et al.* [1997] and *Polasky et al.* [1996] suggest that validity can be improved by a conservative recoding of uncertain responses to "no" responses. In the YES10 model, predictability was improved. Less-drastic modeling approaches are proposed to allow for incorporation of uncertainty. However, as shown by the results of *Ready et al.* [1995], allowing for uncertainty of the "no" responses actually increases mean WTP. While explicitly incorporating uncertainty into modeling of CVM responses appears promising, more research is needed before one can generalize about its net effect.

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